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Self-Repairing Flight Control System



NASA's F-15 HiDEC (highly integrated digital electronic control) research aircraft, in flight over California's Mojave Desert, was the testbed for development of the Self-Repairing Flight Control System.

NASA Photo EC 90-312-30

NASA has successfully demonstrated an aircraft flight control feature that has the potential of saving lives and lowering aircraft maintenance costs.

It is the Self-Repairing Flight Control System (SRFCS), a software addition to an aircraft's digital flight control system that detects failures and damage to ailerons, rudders, elevators, and flaps. The system -- which can be used on nearly all aircraft with digital flight control systems -- then compensates for the component loss by reconfiguring the remaining control surfaces so flight crews can land their aircraft safely. Installed on military aircraft, the unique system would allow aircrews experiencing a control surface failure to complete important tactical missions.

A standout feature of the SRFCS -- also known as the reconfigurable flight control system -- is a cockpit display that presents pilots a visual warning explaining the type of system failure the aircraft has experienced due to a malfunction or combat damage. The readout, which can be

presented on a heads-up display, gives pilots new flight limits such as reduced speed and maneuvering limitations that the failure or damage may impose.

The SRFCS includes a maintenance diagnostic capability. Built-in test and sensor data are used to identify failed components or system faults that often are not seen in ground maintenance. This in-flight diagnostic feature identifies intermittent faults that often occur only during high maneuvering loads, or during high hydraulic-flow requirements. Having the ability to identify faults or failures in advance of post-flight inspections eliminates inconclusive ground checks and excessive maintenance hours.

The SRFCS was successfully flight tested by NASA between December 1989 and March 1990 on an F-15 aircraft at the Dryden Flight Research Center. An advanced version of the SRFCS was successfully tested in 1998 at Dryden on an unpiloted X-36 research vehicle.

System development and flight testing was sponsored by the U.S. Air Force Wright Research and Development Center, Wright-Patterson AFB, Ohio.

The Benefits of a SRFCS

One of NASA's major goals is to reduce the commercial and general aviation accident rate by a factor of five within this decade, and by a factor of 10 within the next 20 years. The SRFCS is considered a major safety innovation that could help NASA achieve these goals -- with emphasis on saving lives, reducing injuries, and making all types of aviation travel much safer.

The immediate benefits of the SRFCS would be seen in the reduction of serious incidents and fatal accidents involving failed or damaged flight control systems. But the benefits of the system extend beyond detecting and overcoming these failures.

The diagnostic capabilities of the SRFCS can reduce ground maintenance time for commercial air carriers. The result would be faster and more efficient service cycles for each aircraft and increased revenue. Easier and faster maintenance diagnostic work also translates into lower maintenance costs and increased operating revenues.

Military forces utilizing the SRFCS on combat and support aircraft would also enjoy reductions in ground maintenance time and expenses, but the greatest benefit to military forces would be a higher aircraft combat readiness rate. Military aircrews would also have a greater chance of completing combat missions following damage to flight control components.

The SRFCS, because of its added safety factor, could also lead to lower insurance costs for owners and operators of commercial and general aviation aircraft.

The SRFCS Test Program

The aircraft used to test and evaluate the SRFCS was Dryden's F-15. It is a research platform that was ideally suited for the program because it was already equipped with the digital system technology that made the research effort possible at a reasonable cost.

The tests were flown between December 1989 and March 1990, and the key objective was to demonstrate real-time flight control surface reconfiguration and maintenance diagnostics technology to the operational community. Flight demonstration is important in validating and evaluating technology for future aircraft.

In today's commercial and military aircraft, the control systems have the power and flight control surface displacement to maneuver the aircraft in a very large flight envelope, with surplus force capacity available from each control surface. In a failure or loss of a control surface, the SRFCs utilizes this capability to reconfigure control commands to the remaining control surfaces and preserve the maneuvering response. When the system senses a failure, it automatically selects the best pre-computed solution from a set of control laws loaded into the aircraft's flight control computer.

On the initial demonstration flight, NASA research pilot James Smolka, flying at Mach 0.7, purposely locked the aircraft's right horizontal stabilator to represent a failure of hydraulic or electronic systems. The self-repairing system instantly reconfigured the remaining stabilator, the ailerons, and rudders to establish aircraft pitch and roll control with the right stabilator remaining in the "failed" state.

A battle damage scenario in which control effectiveness of the right stabilator was changed to simulate flight with 80% of the span missing was also demonstrated. The system correctly identified the "damage" and reset the other flight control surfaces to restore normal controlled flight.

On subsequent test flights, the right stabilator was locked at 2 degrees, 4 degrees, and 6 degrees with "failure" detection accurate each time and flight performance good.

Other battle damage tests included flights that simulated 50% of the stabilator span missing, and a flight that simulated the entire right stabilator being missing. "Failure" detection and flight performance remained excellent.

Tests of the on-board maintenance diagnostics program were also successful. During the tests, five intermittent electrical, mechanical, and hydraulic faults were activated during specific maneuver

conditions, and each was correctly identified by the diagnostic system. After each of the flights, the failure data and appropriate repair instructions were displayed on a ground station screen. If the scenarios had involved an operational aircraft on scheduled flights, the diagnostic program would have facilitated repair work each time to return the aircraft to full flight readiness.

An updated version of the SRFCs was tested and demonstrated at Dryden in 1998 during research flights with the X-36, a vehicle developed to examine performance and maneuvering characteristics of a tailless aircraft. Called the Reconfigurable Control for Tailless Fighter Aircraft project (RESTORE), the vehicle was flown twice to examine advanced SRFCs software and technical results produced by the project were excellent and again validated the concept.

Program Participants

Feasibility studies that led to the SRFCs tests by NASA began in 1984 at the Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio. Ground-based and in-flight simulators verified the data before the system was developed and demonstrated on NASA's F-15 research aircraft.

NASA conducted the tests and evaluations on the F-15 because its digital flight control system was ideally suited for this type of research and test program, and because of Dryden's flight test data acquisition facilities.

The McDonnell Douglas Co., St. Louis, Mo., and the General Electric Aircraft Control Division, Binghamton, N.Y., developed the SRFCs under contract to NASA.

The Air Force Wright Research and Development Center, Wright-Patterson AFB, Ohio sponsored the program.